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EXPERIMENTAL STATION
SUFFIELD, ALBERTA

TECHNICAL MINUTE NO. 103

EFFECTIVENESS OF GIVEN Ct's OF MUSTARD GAS VAPOUR FOR LONG EXPOSURE PERIODS UNDER TROPICAL CONDITIONS

P-6

SUMMARY

1. Twenty-four men were exposed in groups of six under hot humid conditions to a Ct of mustard vapour of 1210-1250 when (t) was varied from 40 minutes to 240 minutes.

2. Under the conditions of these trials, no great difference could be detected in the lesions produced.

3. The number of mon exposed in each group was limited by the capacity of the chamber.

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EXPERIMENTAL STATION

SUFFIELD, ALBERTA

TECHNICAL MINUTE NO. 103

Effectiveness of Given Ct's of Mustard Gas Vapour for Long Exposure Periods Under Tropical Conditions

INTRODUCTION AND OBJECT

1. The results, in some instances communicated privately, of work which has been carried out at different times in the United States and in the United Kingdom suggested that the direct relationship between the physiological effect and the product of the concentration and the time of exposure ("Haber's product") may not hold for the action of Mustard Vapour on the human skin when the times of exposure are short. For example it appeared that a Ct of 300 might possibly be more effective when the time of exposure was 3 min. than when it was 30 min.

2. Since,

(a) Estimates of ammunition expenditure are normally based on the assumption that the time of exposure will be from 4 to 6 hours,

(b) The present estimates as to the physiological effects of given dosages (Ct.) of mustard vapour have, for the most part, been extrapolated from exposure times of from 20 to 60 minutes duration,

it was felt desirable to carry out trials to compare the physiological effect on men when the dosage (Ct.) of mustard vapour remained constant but the time of exposure varied from about 30 minutes to 4 hours.

3. A Ct of 1000 has been accepted as that likely to make casualties of the majority of men exposed under tropical conditions when protected only by a respirator and wearing non-impregnated clothing.

4. The investigation attempted to determine, under simulated tropical conditions in the chamber, the differences in severity, if any, between the physiological effects on the human skin produced by a concentration of 33 mg./m^3 of H vapour over 30 minutes (Ct = 1000) and a concentration of 4 mg./m^3 over 240 minutes (Ct = 1000).

5. For obvious reasons, unprotected men could not be exposed to these Ct's of H vapour. The technique of exposing limited areas of bare skin to vapour by means of vapour cups is open to the criticism that in actual warfare, only small areas of bare skin would be exposed to vapour, the greater portion of the skin being covered by clothing which may well afford some degree of protection. The application of vapour cups to clothing applied over the skin is also of doubtful validity since H vapour probably produces its effects partly by penetration of the clothing and partly by passing through the apertures in the clothing, e.g. at the cuffs, ankles, and various closures.

6. In this investigation, limited areas of the skin were exposed to a Ct of 1200 by means of a technique which attempted to avoid the errors mentioned above. It was assumed that the enemy would not have impregnated clothing available and would wear long-sleeved and long-legged non-impregnated garments.

PROCEDURE

7. Six observers per trial were exposed in the chamber to a Ct of about 1200; t = 40 mins; 2 hours; 4 hours.

8. They were dressed as follows:

Undershirts, long-sleeved, impregnated.
Underpants, long-legged, impregnated.
Shirts, K.D., long sleeved, non-impregnated.
Trousers, K.D., long legged, non-impregnated.
Hoods, U.S. CC2 impregnated.
Respirators - light type.
Socks - impregnated.
Boots

9. The sleeves of the undershirt were rolled up to just above the elbows and fastened with tapes in Trials I and II. In Trials III and IV the sleeves were rolled to a point below the bend of the elbows and secured in the same way. Anti-gas ointment No. 5 was applied to the hands and wrists.

10. The legs of the underpants were rolled up and secured with tapes just below the knees.

11. The cuffs of the non-impregnated K.D. shirts were fastened in the ordinary fashion. The trousers were left open at the bottom.

12. In each trial the men moved from chair to chair every 15 minutes during their exposure. After their exposure they continued to wear their clothing and remained in a warm room for a minimum of 2 hours. After each trial the men were examined at intervals of 24 hours until their lesions were fully developed.

Chamber Conditions

13. Temp erature and humidity were both difficult to maintain at any selected level as there was no regulating equipment by which they could be controlled. Heating was by means of electric radiant heaters and cooling was achieved by cooling the room in which the chamber was located. The relative humidity was increased by injecting steam through one of the ports in the wall of the chamber after the walls, ceiling and floor had been thoroughly wetted by means of a power driven sprayer. The only means of decreasing the relative humidity was by shutting off the flow of steam. The sought-for chamber temperature was between 80-85°F. and the relative humidity 80-85 per cent. These figures varied somewhat and are shown with the pertinent trial. Appendix I gives details of chamber conditions and chemical analysis of the concentrations employed. Appendix III shows the temperature variations and relative humidity of the external conditions during the four days following the trial.

RESULTS

Trial I

14. The exposure was for 40 minutes to a total Ct of 1250. The temperature was 97°F. and the R.H. was 90%. The next 3½ hours were spent in a room at 80°F. Erythema had commenced to develop within 2 hours of exposure.

At 24 hours.

15. All of the men showed erythema and oedema of the arms which involved the elbow joint and made movement very uncomfortable. Four of the men had pin-point vesication of the exposed areas on the arms.

16. Three of the men showed erythema and oedema of the legs and three of the men had intense erythema without oedema of the tissue.

17. One man complained of systemic symptoms of nausea and vomiting.

At 48 hours

18. Five of the six observers showed skin effects which were of the same order of severity, the affected areas on the arms being extensively vesicated and swollen.

19. The involved skin on the legs showed erythema and oedema with commencing pin-point vesication on blanched areas.

Trial II

20. Exposure was for four hours to a Ct of 1250. The temperature was 87°F. and R.H. varied between 75-85%. They were removed from the chamber at the end of each hour for 10 minutes. The 12 hours following exposure were spent in a room at 75°F.

At 24 hours:

21. The unprotected areas were involved by erythema. The effects on the arms were more marked than those on the legs.

At 48 hours:

22. Three men showed erythema and oedema of forearms and legs and three men showed erythema alone of these areas.

At 72 hours:

23. Three of the men showed erythema and oedema of the forearms and legs with scattered areas of pin-point vesication.

Trial III

24. Exposure was for 2 hours and five minutes to a Ct of 1250. The temperature was 88°F. and the R.H. 84%. The men did not leave the chamber during the trial. At the end of the exposure the men remained for an additional two hours at room temperature (75°F.).

At 24 hours:

25. All of the men showed intense erythema and oedema of the arms and legs. Three of the men showed vesication of the forearms and one man had vesication of the calf of one leg.

At 48 hours:

26. All men showed intense erythema and oedema of the forearms. Three of the men had large vesicles on the forearms, 2 men showed many small vesicles and one had pin-point vesication in this region.

27. All of the men had intense erythema and oedema of the calves of the legs, one man having several large vesicles and two men showing extensive pin-point vesication in this area.

At 72 Hours

28. All of the men showed intensive erythema and oedema of the forearms with wide spread vesication of these areas.

29. Six men showed extensive erythema and oedema of the calves of their legs. Two men had large vesicles of the legs and one man showed pin-point vesication.

30. No further progress was made in the lesions after this time.

Trial IV

31. Exposure was for 4 hours to a Ct of 1210. The temperature was 92° and the R.H. was 90 per cent. Movement while in the chamber was carried out as in Trials II and III. The men were removed from the chamber at 2 hours for a 10 minute period. At the end of their exposure the men remained in a warm room for 2 hours (temp. 80°F.).

At 24 Hours

32. All of the men showed erythema and oedema of the skin of the forearms. Three men showed pin-point vesication of this area. Five of the men showed erythema and oedema of the calves of their legs, one man showed erythema with no oedema of this area.

At 48 Hours

33. All of the men still showed erythema and oedema of the skin of the forearm. Three of the men showed extensive vesication of this area with moderate sized vesicles. Two of the men showed pin-point vesication of this area.

34. All of the men showed erythema and oedema of the legs. One man had large vesicles of the calves of his legs. Three men had pin-point vesicles on this area.

DISCUSSION

35. The results (tabulated in Appendix II) do not indicate any significant differences in effects between exposure times of 40 min., 125 min. and 4 hours (Trials I, III and IV). In Trial II, in which the exposure was 4 hours, the lesions were somewhat milder, but it should be noted that, in this trial, the men were removed from the chamber for 10 minutes in every hour instead of for the one period of 10 minutes at the end of 2 hours adopted in Trial IV. Although the aggregate exposure was for 4 hours these breaks may have had some mitigating effect on the results.

36. The results afford some confirmation that, for unprotected men under hot, humid conditions, a dosage (Ct.) of the order of 1000 should cause a high percentage of absolute casualties with any period of exposure likely to come under consideration. It is possible that a dosage of this magnitude is too high for small differences in the severity of the burns to become apparent, and that if the series of trials were repeated at a dosage of (say) 500 the differences, if any, caused by varying the time of exposure, might be more apparent.

CONCLUSIONS

37. Under the conditions of these trials, no great difference could be detected in the reaction of men exposed to a Ct of mustard vapour of 1210 to 1250 under hot humid conditions when the time was varied from 40 minutes to 240 minutes.

RECOMMENDATIONS

38. If this trial is to be repeated, it is recommended that a lower concentration be selected and a more rigid control be maintained on temperature, relative humidity and the uniform addition of mustard vapour throughout the trials.

These trials were carried out by Lt. Col. Somerville R.A.M.C. and S/L Dobson R.C.A.F. of the Physiology Section, Experimental Station, Suffield, Alberta.

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APPENDIX I

Trial I (Carried out 1 Feb 45)

The following H concentrations were found:-

Time			C, mg/m^3	
Z + 2	- Z + 7	=	23 mg/m^3	
Z + 7	- Z + 12	=	27 mg/m^3	
Z + 13	- Z + 18	=	25 mg/m^3	
Z + 18	- Z + 23	=	36 mg/m^3	
Z - Z + 18		=	28 mg/m^3	Ct = 500
Z + 18	- Z + 40	=	34 " "	Ct = 750

Ct, Z - Z + 40 = 1250

Meteorological Conditions

At start	T = 97°	R.H. = 83%.
At finish	T = 98°	R.H. = 93%
Average	T = 97°	R.H. = 90%

Trial II (Carried out 6 Feb 45)

Time	C, mg./m^3	Ct
Z	9.1	0
Z + 15	6.1	140
Z + 30	4.8	230
45	5.3	300
60	4.0	380
75	5.5	440
90	6.1	525
105	6.0	615
120	4.2	705
135	4.0	765
150	5	825
165	3.9	885
180	5.2	945
195	6.3	1025
210	5.4	1120
225	4.5	1200
240		1260

Rest periods were not counted in the exposure time. They occurred at Z + 60, Z + 120, Z + 180.

Total Ct = 1250

Meteorological Conditions

At start	T = 86°	R.H. = 75%
At Finish	T = 88°	R.H. = 85%
Average	T = 87°	R.H. = 81.5%

An independent trial in which samples were taken from a chamber containing men in CC_2 impregnated clothing showed essentially no H present.

The impregnite does not give off vapours which react with the iodoplatinate reagent under these conditions.

Trial III (Carried out 25 April 45)

Time	Cumulative Ct by Iodoplatinate Method
Z - Z + 15	160
Z + 15 - 30	330
Z + 30 - 45	490
Z + 45 - 60	630
Z + 60 - 75	710
Z + 75 - 90	910
Z + 90 - 105	1060
Z + 105 - 125	1250

Meteorological Conditions

At start	T = 87°	R.H. = 75%
At finish	T = 88°	R.H. = 84%
Average	T = 88°	R.H. = 84%

Analyses were done by the iodoplatinate method, and the DB3 method.

Results agree well, the Ct by DB3 method being 1400.

Lowest concentration of H vapour = 8.5 mg./m^3 (15 min. av.)

Highest concentration of vapour = 12.5 mg./m^3 (15 min. av.)

Average concentration of H vapour = 10.0 mg./m^3 (15min. av.)

APPENDIX I (Cont'd)

Trial IV (Carried out 12 Jun 45)

H Concentrations

Time	Cumulative Ct By Iodoplatinate	By DB3
7 - 4 + 30	140	
60	230	
90	370	
120	530	710
150	720	
180	900	
210	1060	
235	1210	1610

The agreement between Cts found by iodoplatinate and DB3 methods is not good. No explanation can be offered, other than inhomogeniety within the chamber. In all four trials to date, the iodoplatinate samples have been taken at the same port, and results should therefore be comparable.

Meteorological conditions

	Temperature	R.H.
Average	92°	90%
Maximum	93°	95%
Minimum	89°	75%

Lowest concentration of H vapour = 2.80 mg./m^3 (15 min. av. Iodo. method)

Highest " " H " 7.00 " " " " " " "

Average " " H " 5.10 " " " " " " "

APPENDIX II

SUMMARY OF RESULTS OF OBSERVERS' LESIONS

	TRIAL I	TRIAL II	TRIAL III	TRIAL IV
24 hrs.	**Arms** E 3 — E+ 3 — V 4 — ppv 2 **Legs** E 3 — E+ 3 — V — ppv	**Arms** E 6 — E+ — V — ppv **Legs** E 6 — E+ — V — ppv	**Arms** E — E+ 6 — V 3 — ppv E — E+ 6 — V 1 — ppv	**Arms** E — E+ 6 — V — ppv E 1 — E+ 5 — V
48 hrs.	**Arms** E — E+ 3 — V 6 — ppv **Legs** E — E+ 3 — V — ppv	**Arms** E 3 — E+ 3 — V — ppv **Legs** E 3 — E+ 3 — V — ppv	**Arms** E — E+ 6 — V 5 — ppv 1 E — E+ 6 — V 1 — ppv 2	**Arms** E — E+ 6 — V 3 — ppv 2 **Legs** E — E+ 6 — V 1 — ppv 3
72 hrs.		**Arms** E 5 — E+ 3 — V — ppv 3 **Legs** E 3 — E+ 3 — V — ppv 3	**Arms** E — E+ 6 — V 6 — ppv **Legs** E — E+ 6 — V 2 — ppv 1	**Arms** E — E+ 6 — V 6 — ppv **Legs** E — E+ 6 — V 5 — ppv

APPENDIX III

TEMPERATURES AND RELATIVE HUMIDITIES ON DAYS OF TRIALS AND FOLLOWING 96 HOURS.

DATE	MIN. TEMP. (°F)	MAX. TEMP (°F)	MEAN R.H. %
TRIAL I			
1 FEB 45	-14	6	95
2 FEB 45	-4	4	93
3 FEB 45	-8	6	90
4 FEB 45	-1	33	87
5 FEB 45	8	22	91
TRIAL III			
25 APR 45	23	37	83
26 APR 45	16	50	76
27 APR 45	32	38	91
28 APR 45	29	38	86
29 APR 45	26	59	48
TRIAL II			
12 JUNE 45	39	66	57
13 JUNE 45	36	60	71
14 JUNE 45	43	66	70
15 JUNE 45	41	67	64
16 JUNE 45	43	72	71

NOTE: Temperature inside buildings is maintained around 75 ± 5 °F.

As all arms and legs were bandaged from Z + 24 hrs. for the following week the temperature of the lesions was probably around 98°F.

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